USE OF DYNAMIC UNDER-KEEL CLEARANCE (DUKC®) TECHNOLOGY ON THE ST LAWRENCE RIVER

BENN, LAURENCE. SENIOR ENGINEER, OMC INTERNATIONAL
DAGENAIS, DANIEL. VICE PRESIDENT OPERATIONS, MONTREAL PORT AUTHORITY
TURNER, MATTHEW. PROJECT MANAGEMENT OFFICER, OMC INTERNATIONAL

SUMMARY

The St Lawrence DUKC® system is an e-Nav solution designed to ensure every deep draft passage maintains safe UKC, whilst making use of the full water column to safely maximise cargo. The system provides an intelligent way to safely manage the shift to larger, deeper vessels by managing UKC and air draft in a scientific and consistent way. The St Lawrence DUKC® system successfully integrates data from a range of user groups and disseminates passage planning information to the relevant stakeholders on the river.

1 INTRODUCTION

In 2013, The Port of Montreal awarded OMC International a tender to implement a DUKC® system in the St Lawrence River. The aim of the system was to allow the various river stakeholders (Port, Coast Guard, pilots and industry) to optimise the use of the water column and ensure the safety of vessels visiting the Port of Montreal. Today this system is in operational trial whilst regulatory approval is underway.

This paper will describe the Port of Montreal (section 2), its trade and other factors that precipitated the decision to implement a DUKC® system. Section 3 will describe the geographic situation and the hydraulic features that influence the DUKC® configuration. The DUKC® methodology is the focus of section 4. Section 5 will discuss the implementation of the DUKC® system to St Lawrence River and paper will finish with some general conclusions.

2 PORT OF MONTREAL

Located on the St Lawrence River, the Port of Montreal is one of the most important in Canada and on North American East Coast. Located 1,600 km inland from the Atlantic, it has the most direct access to the major industrial centres of Toronto, Chicago and Detroit, as well as the rest of Central Canada, the US MidWest and MidNorth (Port of Montreal, 2015a). As such the port provides access to overseas goods for over 100 million people. It is estimated that Port provides over 2 billion dollars value add to Canadian Economy (Port of Montreal, 2015b)

2.1 TRADE

The Port of Montreal handles a mixed range of trades including containers, dry bulk and liquid cargo. In 2014, 30.4 MT of cargo was handled, an increase of 8% on the previous year. Of this total 12.6MT (42%) was containers which is equivalent to almost 1.5 million TEU, 9.2MT of liquid bulk was handled mostly petroleum, and 8.4MT of dry bulk, of which grain, iron ore, salt comprised 80% (Port of Montreal, 2014). The bulk trade is both import and export with grain generally exported and industrial raw materials imported.

These goods were transported on over 2000 vessels that visited the port in 2014. Of these approximately 400 were sailing near to the maximum draft limit in the river.

As well as a busy commercial port, the Port of Montreal is also a major destination for cruise ships with over 56,000 passengers arriving in 2014.

2.2 ST LAWRENCE RIVER DUKC®

The decision to implement a DUKC® was made as part of an electronic navigation project being undertaken by the Port of Montreal in collaboration with the Canadian Coast Guard and the Canadian Hydrographic Service. This project also received Canadian federal funding. While the Port of Montreal has autonomy in scheduling vessel movements, the Canadian Coast Guard is the river's regulatory authority.

One of the factors influencing the implementation of a DUKC® system for the Port of Montreal was the desire to optimize the use of the water column. Historically, additional draft for vessels arriving at the port was obtained through dredging. Between 1850 and 1910 the navigation channel between Quebec City and Montreal was dredged three times increasing the depth from 4.88 m to 7.5 m and then to 10.7 m. Since then no major dredging has been done with the exception of some work in 1992 that increased maximum drafts to 11 m. (Port of Montreal, 2015c)

3 ST LAWRENCE SYSTEM

3.1 SYSTEM OVERVIEW

The St Lawrence River connects the Great Lakes with the St Lawrence Estuary and the Atlantic Ocean. Figure 1 shows the map of the region. Montreal is located on what was historically the most upstream navigable part of the river. Since the 1950s, however the movement of ocean going vessels upstream of Montreal has been made possible by the St Lawrence Seaway. The Seaway is a series of locks and dams starting upstream of Montreal with the St. Lambert Lock and continuing upstream towards the Iroquois Lock and Lake Ontario. The impact of these on waver levels can be seen in the cross section plot in Figure 2. Below Montreal the St Lawrence River flows unrestricted to the Atlantic Ocean.

Figure 1: Map of Great Lakes / St Lawrence River system. Source: Google Maps

The presence of locks limits the size and draft of vessels travelling though the St Lawrence Seaway to the Great Lakes. The maximum dimension of vessels entering the Seaway is: length 225.6 m, width 23.8 m and draft 8.08 m. As the last port before the start of the Seaway, Montreal is the terminal port for the larger Post Panamax vessels that can reach the port.

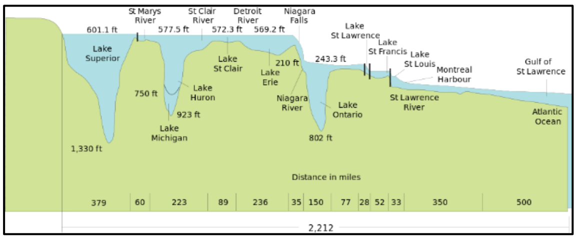


Figure 2: Cross section of water levels and depth of various components of Great Lakes / St Lawrence system.

Source: USACE, 2011

The St Lawrence River flows into the St Lawrence Estuary downriver from Quebec City. Water depths in the estuary which leads to the Gulf of St Lawrence are deeper and Post Panamax vessels with drafts exceeding 13 m regularly visit the Port of Quebec. The St Lawrence estuary is tidal and brackish with salinity increase with proximity to the ocean.

Vessels of up to 11 m draft can travel along the St Lawrence River between the naturally deep St Lawrence Estuary and the 8 m draft limited locks of the Seaway. Thus partially loaded Post Panamax vessels can sail this section of the St Lawrence River to discharge at the Port of Montreal. This section of the St Lawrence River between Montreal and Quebec City is covered by the DUKC® system.

3.2 ST LAWRENCE RIVER

From a hydraulic perspective the section of the St Lawrence River between Montreal and Quebec City can be understood as two separate systems. The division of these two systems is about half way between Montreal and Quebec City, at the city of Trois-Rivieres at the northern end of Lac St-Pierre.

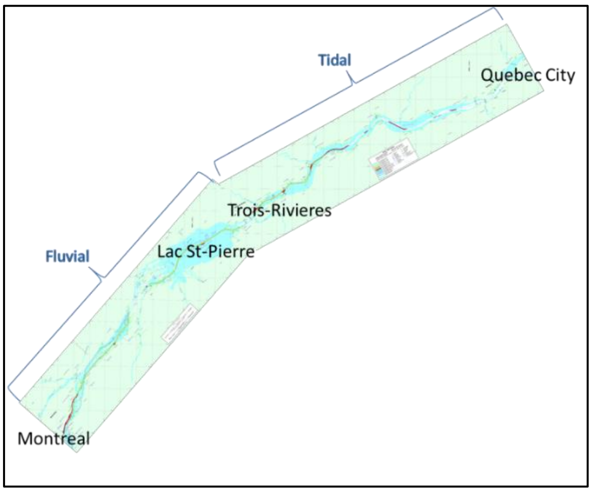


Figure 4: Area covered by DUKC® system.

The upper section is a pure riverine system with no tidal influence. As a non-tidal riverine system maximum draft is the main focus for vessels transiting this section of the river and the maximum drafts available are governed by water level.

Water levels in this upper half of the river are controlled by the upstream river discharge primarily coming from Lake Ontario. As the upstream is a regulated system, there is some ability to control the water level. Indeed for an arriving deep draft vessel that exceeds the maximum draft levels in the river, the port has the ability to request additional flows to increase the water level to accommodate this deeper vessel. This "borrowed" water is paid back via reduced flows (lower water levels) over the subsequent weeks.

The water level of the downstream section of the St Lawrence River from Trois-Rivieres to Quebec City is tidally influenced and can be classified as a hydraulically mixed system. For navigation in hydraulically mixed systems the focus changes from maximum draft to the availability of sailing windows for a given draft: At what times can a vessel with a certain draft safely sail through the river.

As these two sections are connected, the maximum drafts of vessels travelling between Montreal and Quebec City are controlled by the upstream water levels, and the times of transit are controlled by the sailing windows in the downstream section. This situation is illustrated by the schematic in Figure 4.

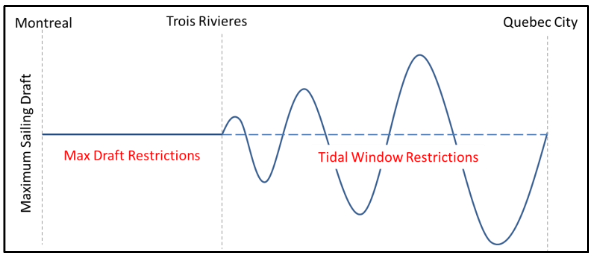


Figure 3: Schematic of draft limits for vessels transiting between Port of Montreal and Quebec City.

3.3 Existing Navigational rules

The present navigational rules that control the times of sailing and maximum drafts can be classified as an advanced static rule. Two look up tables, one for container vessels and one for other vessels, are used to determine the squat estimation based on the vessel's beam. The squat estimation is only made for a vessel travelling at 7 knots. An extra safety allowance of 0.61 m is also made to cover all other unknowns (CCG, 2015a).

Water level forecasts are made manually by the Coast Guard based on tidal predictions and the prevailing weather. The UKC requirements are checked for each vessel transiting the St Lawrence River at 9 predefined single locations. At 6 of those locations, where water levels are tidally influenced, times of sailing restrictions are also determined.

While this UKC check is performed for passage planning by the Coast Guard, it does not ensure that the UKC is maintained for the actual passage. It is a manual and static process and is not easily modified to take account of any deviations from the planned transit such as changes in planned speeds or any changes in water level or currents from those predicted. Most vessels travel faster than 7 knots along the river, exceeding the squat allowances made in the initial UKC check. Analysis of the manual water level forecasts has also shown that a greater level of accuracy can be achieved by using automated real-time forecasts provided by the Canadian Hydrographic Service. This service is called SPINE, which stands for Service de Prévision et d'Interpolation des Niveaux d'Eau, (Water Level Forecast and Interpolation Web Service in English).

As well as maximum draft rules there are some other (non-UKC) restrictions in place that limit times of sailing. These restrictions include air draft.

A number of bridges and high voltage power lines cross the St Lawrence River. These structures impose an upper limit on the height of a vessel (air draft). In this case higher water levels tend to restrict sailings, by reducing the distance between the water and the lowest part of the structure.

4 DUKC® METHODOLOGY

4.1 STATIC ALLOWANCE

Traditionally, static rules have been used by authorities to ensure the safe transit of a vessel from an under keel clearance (UKC) perspective. Static rules combine all the various factors that influence the UKC requirements of a vessel into a single gross value that is used to determine times of sailings.

However, there are multiple factors that influence the UKC requirements of a transiting vessel. In reality these factors change dynamically depending on vessel, channel and environmental conditions. A general summary of the factors that influence UKC is presented in **Error! Reference source not found.**. For a riverine environment, where swell waves are not present, squat is the generally dominant UKC component. While many various squat formulas exist, actual squat depends on characteristics of the vessel, the channel being traversed, speed through water as well as water depth.

The static rule approach can be view as a top down approach to UKC management. A gross allowance is allowed for and assumed to be sufficient to cover all cases but at any particular time the nett UKC is effectively unknown.

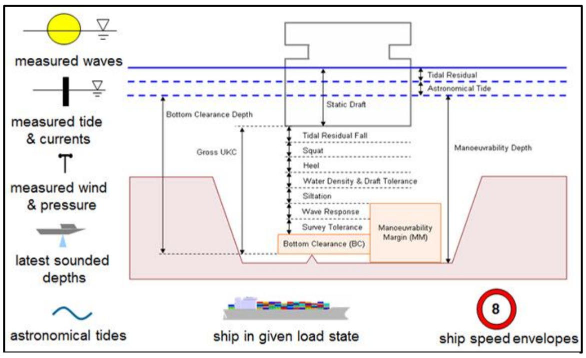


Figure 5: Schematic of the various factors that influence UKC.

The static approach yields two observations, which have both a safety and an economic element. As a gross static allowance is assumed to cover all situations, the actual nett UKC varies and thus the risk of grounding for any given sailing is unknown and indeed situations may exist where the gross allowance is actually insufficient and the navigator is violating safety margin rules.

Further, the gross static allowance is selected with a conservative perspective (to cover all situations); the static rule should be safe in the worst case / conditions. This means that for transits other than the in the worst conditions, the draft or sailing times of vessels are unnecessarily restricted, with obvious economic costs.

4.2 DYNAMIC ALLOWANCE

DUKC® stands for Dynamic UKC and takes a different approach to UKC management, which can essentially be described as a bottom-up approach. This approach defines a minimum nett UKC allowance that must be maintained throughout the transit. To this minimum nett UKC allowance each of the relevant UKC components is assessed and an individual allowance is calculated and added. The final UKC requirement is a summation of the individual component allowances and the nett UKC allowance. The UKC requirement calculated by the DUKC® approach is safety assured because it has at its base a guaranteed safety margin that will not be breached. Effectively, the UKC requirements dynamically adjust to meet the particular requirements of a particular vessel at its particular time of sailing.

As the individual UKC component allowances are calculated on a vessel-by-vessel transit-by-transit basis the economic inefficiency associated with the static rule is avoided. Each transit is conducted against its own UKC requirements. If a particular transit has less UKC requirements than the average then the vessel could load more cargo or sail with wider tidal windows than the average.

As well as vessel conditions and information about the state of the channel, the DUKC® takes a more considered account of the environmental situation influencing the UKC of vessels. For rivers, the major elements are water levels and currents; in the open sea, waves are an additional consideration. Inputs of spatially varying measured and predicted environmental conditions are used by the DUKC® to accurately calculate the UKC requirements for each point along the channel at the times the vessel is expected to pass.

4.3 COMPARISON OF STATIC APPROACH AND DUKC®

Analysis of 44 actual deep draft vessel transits on the St Lawrence River showed that the existing static UKC rules as described in 0 are inappropriate. Each of those vessels transited without incident, but about half of them would not have been allowed if the existing rules were enforced. **Error! Reference source not found.** shows the minimum UKC of each transit as a dot. If the UKC rule was broken during the transit the dot is below 0.0 m. Whilst the vessels consistently (but without incident) broke the static UKC rules, only 1 transit broke the DUKC rule by a very small amount.

This analysis highlighted two key things. Firstly, there is currently no method in place for monitoring or auditing the adherence to the existing UKC rules. Secondly, the pilots are regularly navigating the river despite the static UKC rules implying they shouldn't be. This suggests the static UKC rules are not an accurate reflection of the reality of shipping on the St Lawrence River.

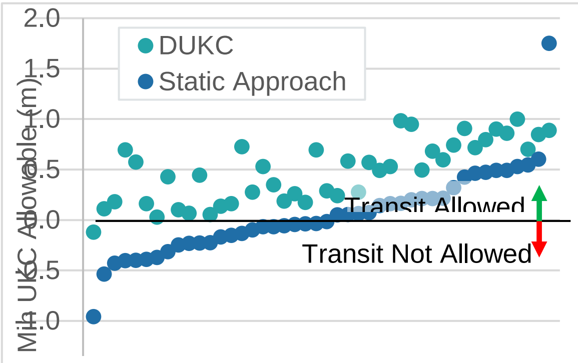


Figure 6: Comparison of DUKC and Static UKC rules for 44 actual deep draft transits. A dot below 0.0 m indicates that transit broke either the Static UKC rules or the DUKC rules. No transit actually grounded.

4.4 DUKC® System

DUKC® is a computer system based on the DUKC® methodology. It is a proven safety and risk management technology and is a recognised e-Navigation technology. The first DUKC® system was developed and installed in 1993 at the Hay Point coal terminal in Queensland, Australia. Since then the technology has been installed in over 20 ports and has ensured the safety of over 100,000 transits. Today DUKC® is recognised as best-practise for UKC management.

Now in its 5th generation, the latest version of DUKC® is web based allowing authorised users to connect with the system. Such authorised users could include planners, VTS operators, regulators, and pilots.

The core functionality of the DUKC® has been to provide users with dynamic passage planning advice on:

- maximum sailing draft (fixed sailing times)
- sailing window times (fixed sailing draft)
- UKC for specific transit (fixed times and drafts)

This core functionality remains in DUKC® Series 5 and has been augmented by more flexibility in transit planning through speed control and a gating engine as well as transit monitoring capabilities. The following figures describe this functionality.

For long term planning a draft and sailing time planning service exists. This service uses preconfigured speed profiles and climate or user specified environmental conditions to obtain advice on maximum drafts or sailing

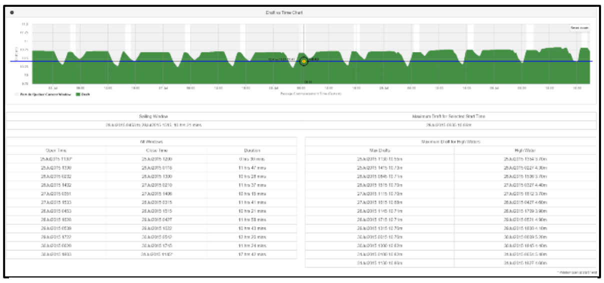


Figure 7: Draft and Sailing Time Planning Service.

windows for planning purposes. The image in **Error! Reference source not found.** shows the possible sailing times over a week period for a range of draft levels.

Closer to the time of sailing a transit planning service allows more detailed planning of the transit to occur. The transit planning service allows the transit to be planned with a higher level of refinement. This includes more detailed information about the load state of the vessel and more control over the planned speeds rather than the pre-configured profiles used in voyage planning. An example of the transit

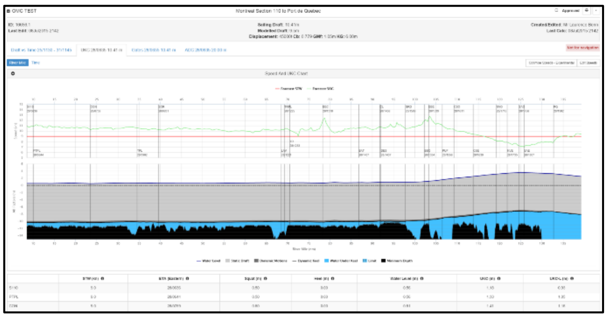


Figure 6: Transit Planning Service.

planning service is shown in **Error! Reference source not found.**.

The transit plan provides more detailed transit planning advice (**Error! Reference source not found.**) than is available in the draft and sailing time planning (**Error! Reference source not found.**). The upper panel indicates the input data used to calculate the result including vessel particulars, loading. The lower panel presents an along channel view of the UKC anticipated over the course of the transit. **Error! Reference source not found.** displays the results of the optional gating engine. For long transits with numerous controlling points along the way the display from the gating engine indicates the interaction between planned speed at the various critical points, the available windows at

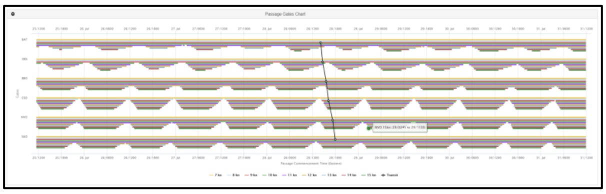


Figure 8: Gating Planning Service.

the critical points for those various planned speed options, and how the planned transit interacts with the availability of windows at the various critical points.

If an AIS feed is made available to the DUKC® system, then the Transit Monitoring Service can be configured. The Transit Monitoring Service links a vessel's position with its DUKC® planned

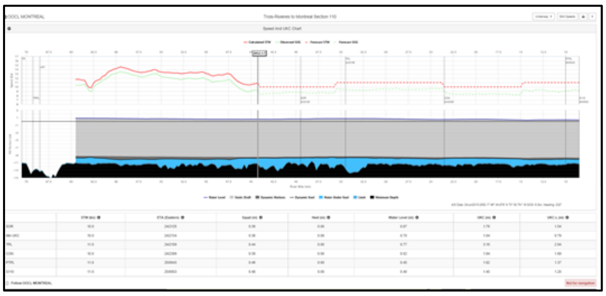


Figure 9: Transit Monitoring Service.

transit information through its MMSI number. It allows the vessel's passage along the transit to be tracked. As the vessel's position and speed change, the UKC advice can be regularly recalculated using the latest environmental information. An example of the transit monitoring service is shown in **Error! Reference source not found.**.

The additional feature in the transit monitoring results is the display of the actual speeds undertaken by the vessel and the planned speeds for the remainder of the transit. Because the speeds in the passage plan can be edited during the transit monitoring stage, the system can be a used to safely adapt the transit plan to changing situations be they issues with the vessel such as engine problems or deteriorating environmental conditions.

5 CONFIGURATION

To develop a DUKC® system for the Port of Montreal to cover the transit from Montreal to Quebec City, the DUKC® system needed to be customised to meet the particular needs of the port and the other stakeholders.

5.1 SAILING ROUTES

The transit from Montreal to Quebec City take between 12 and 20 hours depending on transit direction and the vessel speed. There is a change of pilots halfway along the route at Trois-Rivieres. Because of the existence of the two hydraulic regimes, both with separate pilotage, the upriver pilots need to time vessels travelling downstream to allow for sailing windows to open in the tidally influenced part of the river. The DUKC® system displays this information clearly to help pilots manage the full passage plan. This helps to ensure that when the downriver pilot takes over the vessel can proceed without tidal restrictions.

As well as the main Port of Montreal there are a further four port terminals along the route: Contrecoeur, Sorel, Bécancour and Trois-Rivieres. In the riverine section of the route upstream from Trois-Rivieres there are 3 anchorages. All of these origin/destination points (with the exception of Bécancour) were configured in the DUKC®. In total there were 9 potential (**Error! Reference source not found.**) and 64 route configurations with the various permutations available. Each of these sailing routes combinations was configured in the

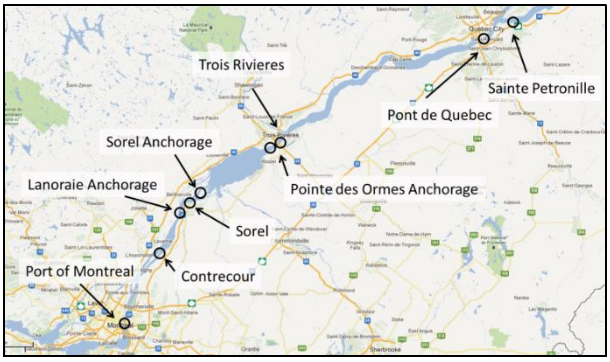


Figure 10: Map of destinations. Source: Google Maps

DUKC®.

5.2 Gating and Optimisation

The DUKC® system allows passage planning with speed ranges between 7 and 15 knots, to better reflect the actual vessel speeds on the river, rather than the single 7 knots used by the existing static process. Therefore for each of the 64 route combinations a predefined transit at each of the 9 speed options was developed. In total there were 576 passage plan combinations produced for the system.

Upstream of Trois-Rivieres the bathymetry is maintained with a minimum depth of 11.3 m. However downstream there are a number of shallower sections of 10.7 m maintained depth, interspaced with some naturally deeper sections. For a draft restricted vessel that is at the edge of a sailing window, the ability to optimise the vessel speed to maintain sufficient UKC but to minimise the travel is an important feature. The DUKC® gating engine with the concept of gates and legs assists with this issue.

Each of the shallower sections was defined as a leg and gates were defined at either side to cover the vessels travelling upriver or down river (**Error! Reference source not found.**). When a transit is being planned the gating engine calculates the UKC through each leg for each of the preconfigured speed profiles. These calculations yield a set of times that it is safe to pass through a gate (commence sailing along its respective leg) at a particular speed.

Using this information it would be possible for a pilot to minimise the transit travel time by selecting the fastest allowable leg speed combinations that still enabled the vessel to arrive at the next gate at a speed and time that maintains safe transit.

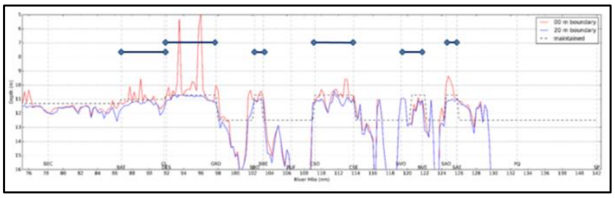
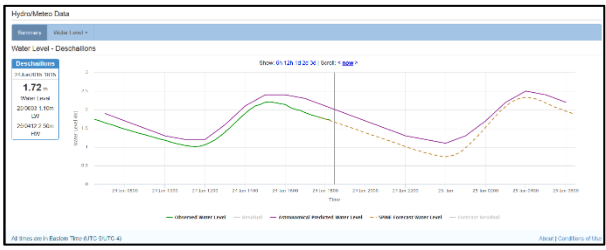


Figure 11: Graph of along channel bathymetric depths. Shallower sections are defined as legs with gates either side.

In total 18 speed control sections were defined over the entire river and within each the speed could be set between 7 and 15 knots. As manually adjusting this large number of section and speed options to identify the route with the minimum travel time would be cumbersome, an experimental optimisation routine was developed to automate the process.

Figure 12: DUKC® monitoring main view



The optimisation routine considered the fastest possible route: constant 15 knots. If this route was infeasible due to UKC limits being exceeded anywhere within the planed transit the planned speeds were systematically reduced until a feasible solution was returned.

5.3 ENVIRONMENTAL DATA INPUT

To undertake the UKC calculations the DUKC® combines vessel and channel information with the latest environmental forecasts for the area. In a riverine environment the main environmental considerations are water level and current speed. In estuary areas density is also an important consideration, but the St Lawrence River is fresh water upstream of Quebec City.

In a typical DUKC®, real time measurements are combined with forecasts to produce blended forecasts of the environmental conditions. However, in the case of the St Lawrence River, SPINE already provides this information and the DUKC® system is able to use these forecasts directly. These forecasts predict the water level up to 30 days into the future (CHS, 2015). The DUKC® model regularly downloads the SPINE forecasts at 99 locations along the river. This provides a high resolution water surface plane for the full length of the river. This water plane is automatically updated every 15 minutes with new SPINE forecasts.

Additionally for user convenience the water levels at the 13 tide gauges along the river are displayed by the MetOcean view of the DUKC® along with the astronomical and SPINE predictions, giving users a complete overview of the trends in historic and forecasts water levels (**Error! Reference source not found.**).

The information about anticipated dam releases from Lake Ontario are not currently available to SPINE. As noted previously the Port has the ability to request additional dam releases, so an additional functionality was required to allow the port to plan for such cases. A water level simulation mode was specially developed that allowed a constant water level offset to be applied to all water levels. This feature is available on a transit by transit basis.

There are two sources of current forecasts that are used by the DUKC®. Downstream of Trois-Rivieres in the tidal section of the river current forecasts are extracted from the St Lawrence Global Observatory model. This model integrates tidal influence and mean freshwater runoff from the St. Lawrence River (SLGO, 2015). Upstream of Trois-Rivieres, the DUKC® uses a lookup table of river flows supplied by the Canadian Coast Guard. The table predicts current speed based on water level for a series of locations.

Figure 13: Tabular report on Air Draft Clearance

5.4 BATHYMETRY

The bed depths in a river such as the St Lawrence, which is subject to strong currents that mobilise sediment, are constantly fluctuating. The Canadian Coast Guard is charged with maintaining the shipping channels in the St Lawrence River and conduct ongoing dredging (CCG 2015b). In conjunction, the Canadian Hydrographic Service regularly performs high resolution surveys of the channel bathymetry. These surveys are provided in an S-102 geotiff format. By regularly updating the DUKC® with the latest sounded depth the system users can be assured that the UKC advice is based on the most up-to-date information.

5.5 AIR DRAFT

The river between Quebec City and the Port of Montreal is crossed by 3 bridges and 7 power cables. Avoiding a vessel colliding with any of these overhead structures is equally as important as avoiding a vessel grounding. To account for the Air Draft requirements, an Air Draft Clearance (ADC model was developed specifically for the St Lawrence DUKC® system. This model is specified as:

ADC = Structure Height – Air – Draft – Water Level

For conservatism no allowance for vessel squat was is made in the ADC calculation. In winter periods, ice build-up on the power cables can produce substantial additional sag lowering the clearance level of power cables. To account for this an ADC is calculated for the normal height of the structure and for the height under ice conditions. The ADC is calculated during planning and presented to the user in a tabular form (**Error! Reference source not found.**).

Draft vs Time 23/2345 - 27/1345 | UKC 24/1334 8.00 m | Gates 24/1334 8.00 m | ADC 24/1334 20.00 m

Overhead Structure	Condition	Overhead Height (m)	ETA	Water Level (m)	ADC (m)	ADC Limit (m)
Pont Pierre Laporte - Amont (Cable)	Normal	51.10	24Jun2016 1724	2.07	29.03	0.00
	Ice	38.10	24Jun2016 1724	2.07	16.03	0.00
Pont Pierre Laporte (Bridge)	Normal	55.10	24Jun2016 1724	2.07	33.03	0.00
Pont de Québec - Amont Est (Cable)	Normal	54.10	24Jun2016 1725	2.07	32.03	0.00
	Ice	41.10	24Jun2016 1725	2.07	19.03	0.00
Pont de Québec - Amont Ouest (Cable)	Normal	54.10	24Jun2016 1725	2.07	32.03	0.00
	Ice	41.10	24Jun2016 1725	2.07	19.03	0.00
Pont de Québec (Bridge)	Normal	52.10	24Jun2016 1725	2.07	30.03	0.00

5.6 USER CONTROL

As well as the ability to optimise the use of the water column for navigation whilst maintaining safety, another potential benefit of the DUKC® is the ability to share information amongst the various stakeholders. In the case of the St Lawrence River these stake holders are multiple and include the Port of Montreal, pilots, VTS operators, Canadian Coast Guard as the waterway regulator as well as various agents and industry users.

It is important that each user can access the information relevant to them, but equally important that this access is limited. For example it may be appropriate for an agent to To allow for the control of access to the information, the DUKC® has a user management service that allows groups and roles to be defined which control the access and actions of users on the system. Each

5.7 IN TRANSIT MONITORING

An AIS feed of all vessels with draft greater than 8 m in the area of the DUKC® St Lawrence River system is provided by the Canadian Coast Guard. This real-time data feed allows the DUKC® monitoring functionality of the system to be enabled.

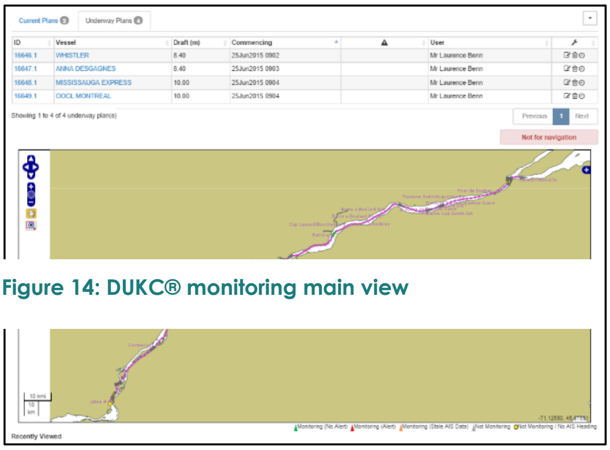


Figure 14: DUKC® monitoring main view

The main view (**Error! Reference source not found.**) of the DUKC® monitoring gives a map view of all the area covered by the system as well as displaying position of all vessels presently identified from the AIS data. The table above lists those that are being actively monitored by the DUKC® system.

Vessels become actively monitored in one of two ways: either a previously authorised transit plan automatically starts active monitoring when that vessel is detected by the system as having commenced the transit. I.e. the monitoring does not begin until the vessel leaves its berth, or enters the seaward end of the waterway. Alternatively active monitoring can be begun on-the-fly on a vessel without an

undertake long term voyage planning to assess whether an anticipated voyage is likely to have sufficient UKC on arrival, however it may not be appropriate for that same agent to make an assessment on the appropriate speeds for that vessel on arrival or as it is transiting through the system.

authorised user is given their own account and assigned to a group or role as necessary.

existing transit plan by selecting the vessel directly on the In-Transit map and then entering the plan details.

6 CONCLUSION

The St Lawrence DUKC® was initiated by the Canadian Coast Guard, the Canadian Hydrographic Survey and the Port of Montreal as part of an e-Navigation project. The main focus of the project was to optimise the use of the water column and enhancing the safety of navigation in the St Lawrence River.

As well as meeting this primary aim, the system is able to act as a central hub of UKC advice to the various stakeholders and it promises additional benefits in terms of greater sharing of information amongst the various stakeholders. Whilst the system is still formally in a trial phase it is anticipated that these benefits will become more concrete as the system transitions to operational usage.

The implementation of the DUKC® system for a purely riverine environment like the St Lawrence River demonstrates that the DUKC® technology can be successfully applied to such a waterway, allowing riverine users to benefit from the enhanced safety and economic benefits, that come from the UKC planning and monitoring advice that the DUKC® provides.

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